Evaluation & Response Strategies

I. Introduction
   (1) Purpose
      1. Define scoping strategies for potentially induced seismicity evaluations
         a. Utilize "tools" described in sections 4, 5, 6 & 7
         b. Evaluation strategies when siteing new Class II wells
         c. Evaluation strategies when a Class II well is suspected of causing induced seismicity
      2. Define response strategies for potentially induced seismicity
         a. Response strategies when siteing new Class II wells
         b. Response strategies when a Class II well is suspected of causing induced seismicity

II. Evaluation Strategies
   (1) Introduction
      1. Because of technical considerations regarding the geomechanical mechanisms for inducing seismicity, each evaluation should be event (site) specific
         a. Geology/stratigraphy
         b. Hydrogeologic characteristics
         c. Insitu stress properties
         d. Fault location and orientation
         e. Well operational characteristics
      2. Each evaluation should be fit for purpose
         a. Evaluation for siteing a new well
         b. Evaluation for a well suspected of causing induced seismicity
   (2) Data to inform evaluation
      1. Seismicity
         a. Historic/recent
         b. Epicenter location and magnitude
            (1) Regional seismicity will have larger the error (horizontal & vertical) due to density of seismometers...see section 6
            (2) Location specific data to identify location of fault requires local array and extended monitoring...see section 6
            (3) Lower magnitude determinations requires local array...see section 6
            (4) Variability in private array data versus public array will require calibration of the velocity model
         c. Ground motion vs magnitude
      2. Injection well operational parameters
         a. Injection volume and water quality
            (1) Daily total
            (2) Injectate specific gravity

b. Cumulative volume with time for use in reservoir evaluations
c. Injection pressure
(1) Daily maximum pressure
(a) Note: injection pressure increase may be caused by near bore phenomenon and not a result of an increase in formation pressure capable of perturbation away from well towards fault
i. Scaling
ii. Formation plugging

3. Geology
a. General stratigraphy
b. Depth of basement rock
c. Presence of sealing layers
d. Target injection formation hydrogeologic parameters

4. Fault data
a. Location
b. Orientation
- **Will require open bore logging using proper tools**

c. Stress conditions
- **In-stress data not available unless there is a core for laboratory testing or data collected from a differential fracture injection test or full hydraulic fracturing is available**

(3) Area demographics
a. Location of infrastructure and public/private structures
b. Location of reservoirs and dams
c. Assessment of current infrastructure conditions

(4) Data Evaluation
1. Reservoir...see section 4
a. Defines reservoir pressure changes
2. Geomechanical/hydrological modeling...see section 4
a. Defines pore pressure perturbation
3. Ground Motion Modeling...see section 5
a. Defines potential impact within study area

III. Response Strategies

(1) Response Strategy Overview
1. All responses are reaction to something: "If This...Than That"
2. General forms of a response strategy used to administer the "If this...than this" strategy
a. Decision Tree
(1) EPA document
(2) AXPC document
b. Traffic Light System...
c. Areas of Interest
(1) Oklahoma
(2) Kansas

d. EGS protocol

3. Response strategy should included a stated goal such as:

a. Mitigation of risk that an induced seismic event could happen

b. Mitigation of risk from a detected event

c. Mitigation of risk from a felt event

d. Mitigation of risk from a damaging event

4. Response strategy should be fit for purpose

a. Demographics

5. Two general categories of response strategy

a. Response Strategy for siteing a new well

b. Response Strategy for a well suspected of induced seismicity

(2) "If This...Than That"

1. If this...

a. ...permit application for new well

b. ...event happens

(1) Epicenter occurs within a specified distance of injection well

(2) Specified ground motion / magnitude occurs within a specified distance of injection well

c. ...events happen (area of concern)

(1) A cluster of a specified number of events with a specified ground motion / magnitude occurs within a specified distance of injection well

d. ...evaluation determines this

(1) Well is located within a specified distance of a critically stressed fault

(2) Increase in flow/pressure results in an increase in seismicity

(3) Seismic event is a potentially induced event

(4) Seismic event is not a potentially induced event

2. Than that...

a. ...conduct evaluation

b. ...different location (new well siteing)

c. ...permit condition(s)

(1) Step increases in flow during start up

(2) If a specified ground motion / magnitude event occurs within a specified distance...reduce flow

d. ...operational restriction

(1) Reduced injection flow

(2) Reduced injection pressure

e. ...shut-in well

f. …continue/return to normal operations